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The Use of Patents to Assess National Innovation Systems: Evidences from Spanish Biotechnology

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Abstract

Spain's economy recorded a high rate of growth from the mid-1990s onwards. At the same time, the resources allocated to Research and Development (R&D) grew at a much faster pace than in other European Union (EU) countries. Spain's growth recorded an average rate of 2.93% from the early 1990s to 2004. Over the same period, the average growth in the EU was 0.46%. This circumstance, together with several sound policy decisions implemented between 2004 and 2009, ushered in a "golden age of Spanish biotechnology". In terms of the national patent licenses issued by the Spanish Patent and Trademark Office (SPTO) between 2004 and 2009, the number in biotechnology grew from 84 to 151. However, the current economic situation in Spain, along with a series of political decisions taken over the past two or three years to cut spending on R&D, predicts a sharp downturn in the performance of Spanish biotechnology. This scenario makes Spain one of the best places to study the successes and failures of the management of science and allows transfer this experience to the other international regions. We need to analyze the influence of political decisions as a major factor with a bearing on the quality of science.

Using patents as an indicator of scientific development, this paper analyzes the evolution of the biotechnology sector in Spain and its relationship with scientific policy and the management of R&D.

Keywords: Public R&D funding; Biotechnology management; Patents; Science indicators; Economic crisis

Introduction

The contribution R&D makes to economic growth has become both a political and a social issue in recent years. In today's economy, knowledge is one of the main economic assets, and its management and protection have become the cornerstones of corporate strategy in industrialized nations [1]. The global economic crisis has led to a new political and social scenario in which governments take decisions every day that decide their country's economic future. Nowadays, there is a widely held perception that the higher levels and rates of growth enjoyed by some domestic economies are attributable to the greater success those countries had in exploiting emerging technological opportunities [2]. It is therefore important to analyze the political determinants these countries have been applying over the course of many years. In turn, it is of interest to analyze not only the determinants of success but also the expediency of decisions that were made, and are still being made, in countries that are worse off in economic terms.

Since the mid-1980s, certain authors [3-6] have studied the concept of National Innovation System (NIS) in order to understand the interrelationships between technological development and the decisions of government institutions [7,8]. Since the early 1990s, there have been variations in the approach to this concept that now recognize the importance of developing autonomous innovation systems at local, regional, EU and even global level [9-12].

The aim of this article is therefore to identify the political, social and scientific reasons behind the current situation and the advancement of biotechnology in Spain. This issue is addressed using patents as an indicator of technological development. This study analyzes national patent applications registered in the SPTO, its property distribution and which are therefore legally protected only in Spain. The indicators most studies have so far used to evaluate science and technology systems are the patents registered in international bodies such as the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) or the Japan Patent Office (JPO). However, this study does not seek to draw a comparison at international level. We aim to describe, in as much detail as possible, the situation of a domestic biotechnology system and, in particular, the Spanish case. This paper proposes, among other indicators, the use of national patents in order to evaluate the science conducted in Public Research Organisms (PROs), and universities. According to current patent legislation, all public institutions are required to deposit their inventions as national patents before obtaining licenses with international coverage (for more detail, see article 122 of Spain's Law 11/1986, of 20 March, on Patents; http://www.boe.es/buscar/doc.php?id=BOE-A-1986-7900). Therefore, national patent data recorded in the SPTO provide the latest and most reliable information for assessing the situation of any science and technology sector.

It is important to analyze the design and reconfiguration of innovation systems over the years in order to explain the extreme dependency between politics and science [12,13]. Moreover, Lundvall [14] affirms that the focus upon domestic systems "reflects the fact that national economies differ regarding the structure of their production system and regarding the general institutional set-up".

The Spanish economy grew very quickly from the mid-1990s onwards, as did the country's investment in R&D and its research capacity, measured in terms of the output of published work [15].

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This paper confirms the suggestion made by several authors [16,17] who attributed this progress to the increase in R&D investment and the application of an evaluation policy designed to stimulate scientific production and its international diffusion.

When looking at the annual growth rate of investment in R&D as a percentage of Gross Domestic Product (GDP) from 1994 onwards in Spain, we perceive a major effort to increase spending on this activity. Until 2004, this growth rate was 2.93% in Spain, compared to the EU average of 0.46%, 0.85% in the United States and 2.24% in Japan [18]. However, Spain's starting point for investment in R&D was one of distinct disadvantage, and this growth in investment has not sufficed to reach the average EU investment in R&D relative to GDP. The Lisbon European Council (2000) declared that the average value of investment in R&D relative to GDP in the EU would be 3% by 2010. Spain, with its poor starting position, decided to set its own goal for investment in R&D by 2010 at 2% of its GDP [19]. Spain invested 1.37% of its GDP in R&D in 2010, while the EU average was 1.91%. Both are far from what was agreed in Lisbon in 2000 [20].

The current Spanish Law on Science, Technology and Innovation was enacted in 2011. There had previously been only one piece of legislation on this matter, being introduced in 1986 and laying the foundations for all science and technology plans developed in Spain thereafter. The 1986 law considered the lack of social cues and the absence of public intervention instruments for coordinating the scarce resources available for research [21]. Besides, this law submitted the development of a "National Innovation Plan" (NIP) for Scientific Research and Technological Development to government approval. This plan provides for multi-year periods, the main national objectives for R&D and the means for their realization. These plans are prepared every three or four years and seek to upgrade R&D to adapt to the socioeconomic situation of the moment and correct the mistakes of previous plans.

Apart from the economic decisions included in the different NIPs, it is important to analyze national idiosyncrasies: the size and internal organization of firms, inter-firm relationships, the role of the public sector, the institutional set-up of the financial sector, and the intensity and organization of R&D.

This paper explains how the decisions (economic and non-economic) made in these NIPs can affect the development of biotechnology in Spain, especially in the public sector, as it has a greater presence in this country than the private sector.

Knowledge produced by academic scientists has been identified as one of the most important inputs for technological progress and economic growth. Publicly financed science feeds and supports innovation in the private sector, which in turn creates new jobs and generates income [22]. In the wake of the Lisbon European Council (2000), the trend among European countries has been for an increase in private sector spending on R&D. The target for 2010 was that 60% of national expenditure on R&D would be covered by companies. Spain is one of the world's countries with the highest percentage of public investment in R&D, and therefore the lowest private investment. In 2008, the percentage of Spanish investment in R&D contributed by private companies was 45.5%. The EU average was 55% and the figures for Japan and the US were 74.6% and 64.3%, respectively [18]. This situation has forced Spain to design a very strict system for the management of science and adjust the objectives of Spanish science and technology to profitable public investment. This profitability should begin by encouraging the patenting of the results of public research.

Much of the debate on public patenting has revolved around the question as to whether or not the results of the research by universities and Public Research Organizations (PROs) should be patented [22]. Countries with higher public investment in science and technology should create incentives for patents among public researchers. On the other hand, PROs and universities need to create technology transfer units that are efficient enough to manage and monetize their patents. Technology transfer units should be the ones to manage public patents because they are familiar with both the public sector's complex organization and industry needs, and therefore act as intermediaries between scientists, inventors and companies.

To the extent that patents have become an important issue for universities and PROs, there might be an incentive to shift the resources towards more applied research and to those areas where patents are easily obtained [23,24].

Materials and Methods

The dataset on which the empirical analysis is based was compiled specifically for the purpose this study. The database has been constructed using data from all the biotechnology sections at the SPTO. Biotechnology patents are identified using the following list of International Patent Classification (IPC) codes: A01H1/00, A01H4/00, A61K38/00, A61K39/00, A61K48/00, C02F3/34, C07G(11/00,13/00,15/00), C07K(4/00,14/00,16/00 ,17/00,19/00), C12M, C12N, C12P, C12Q, C12S, G01N27/327, G01N33(5 3,54,55,57,68,74,78,88,92) [25]. We analyzed the time period between 1990 and 2010. 1990 is considered the starting point for patents in biotechnology at global level [26].

We decided to use data on Spanish national patents in order to compare this information with international Spanish data registered in other patent offices, such as EPO or USPTO, as indicators of science and technology quality.

Macroeconomic data on Spanish R&D were collected from Spain's National Statistics Office. International macroeconomic data were obtained from OECD and Eurostat databases. In certain cases, the latest international data published by the OECD are prior to 2010.

Data for "status of patent" are used as indicator of the benefits that different organizations obtain from their patents as previously reported by Belda et al. [27]. Furthermore, we assume that a correct interpretation of these data allows detecting erroneous management policies.

Results and Discussion

The relationship between investment and quality of science seems obvious, and it has been studied at some length by Adams and Griliches [28] and Payne and Siow [29]. Belda et al. [27] has examined the relationship between Spanish R&D investment and the development of biotechnology in Spain (measured by patent applications in the SPTO). Now, they found that there is a close relationship between investment and results solely in the field of biotechnology (Figure 1A). However, when comparing the response of biotechnology to financial investment in R&D and the same response in other areas of science and technology, we have found a lower dependence between R&D investment and the overall performance of science and technology (Figure 1B). This response by the biotechnology sector and the importance of a proper management of biotechnology resources have already been studied and confirmed by Yang et al. [30].

The worldwide biotechnology industry is characterized by its large R&D investments, with uncertain results and frequently without

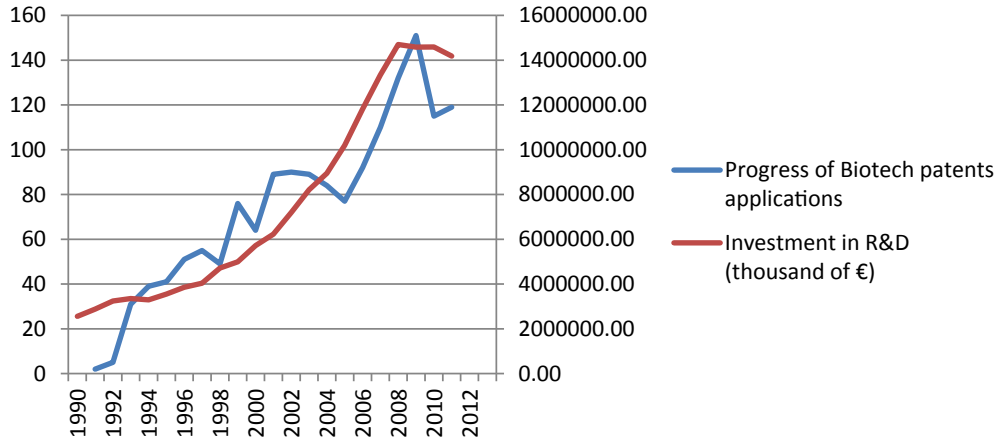

Figure 1A: Spanish biotechnology patent requests and Spanish investment in R&D, public and private investment.

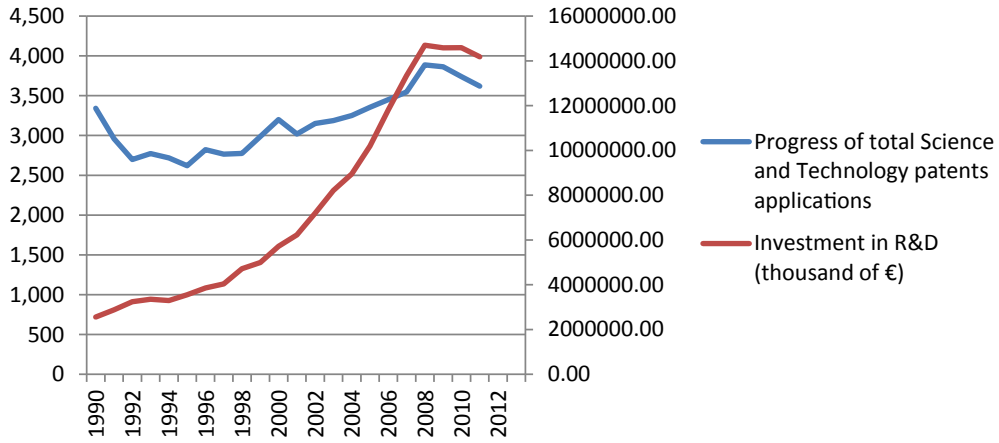

Figure 1B: Spanish general patent requests and Spanish investment in R&D, public and private investment.

benefits [30]. However, the Spanish case seems quite different [27]. Figure 1A confirms a very close correlation between the total investment in R&D and national performance in biotechnological research. Due to low private investment in R&D in Spain, public spending on R&D is primarily responsible for the variations in scientific results. Figure 2 shows where public research in Spain outperforms the results of the private sector nationwide. Spanish public research accumulated 1282 patent applications from 1990 to 2011 (717 by universities and 565 by PROs, including CSIC–Spanish Council for Scientific Research), while Spanish biotechnology companies accounted for 389 in the same period. However, when comparing the data on national patent applications with the Spanish data from international offices such as the USPTO, the graph is inverted. In this case, from 1990 to 2009, Spanish biotechnology companies owned 167 patents, while universities and PROs (including CSIC) accounted for 32 and 35, [31]. Private companies devote their resources to obtaining patents with worldwide coverage. These results suggest a clear relationship whereby high domestic public investment involves a high scientific output in the public sphere whose industrial interest is generally limited to Spanish territory. These results confirm that the national patent applications made to the SPTO are a very reliable indicator of the state of biotechnology in Spain.

Using patents as an indicator of the quality of science, we seek an explanation for the variations in Spanish patent applications in political decisions on investment in R&D reflected in successive NIPs. Understanding the links between the actors involved in the innovation process (researchers, policymakers and science managers) is the key to improving a country's performance in innovation [32].

According to Belda et al. [27], Figure 1A shows four periods of intense activity: 1992-1993, 1998-1999, 2000-2001 and 2005-2011 (last date evaluated). The timeframe between 2001 and 2005 shows a long period of decline in the number of patent applications and, therefore, research activity in Spain. The reason may lie in the National Biotechnology Program, designed in 1996 and kept in force until 1999. This program, rolled out in 1996 by the Spanish Ministry of the Economy and Innovation, focuses all its efforts on adapting Spain's biotechnological research to the "European Framework Programme". Scientific managers may well have failed in their remit to obtain profitable research outcomes. However, this phenomenon has also been observed both in the other EU member states and in the US, Japan and Canada. It is understood that this decline has been caused by several factors, such as the completion of the Human Genome Project in 1998, which led to a decrease in DNA-related patents from 2001 onwards, an economic crisis that affected the US biotechnology industry in 2000, and a change in patent laws rendered DNA patenting more restrictive

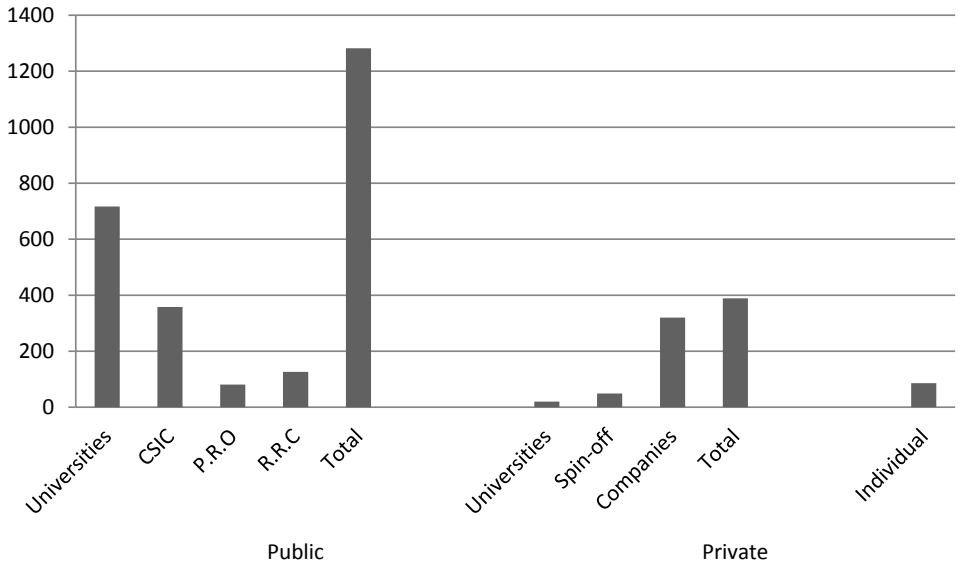

Figure 2: Distribution of biotechnology patent requests in Spain. The public sector is divided into universities, CSIC (Spanish National Research Council), PROs (other national Public Research Organizations) and RRCs (Regional Research Centers). The private sector is divided into universities, spin-offs and private companies.

in this area [31]. Spanish biotechnology would be indirectly affected by these events.

Finally, Figure 1A shows sharp growth in biotechnology patent applications. Between 2005 and 2009, the number of biotechnology patents in Spain doubled (77 applications in 2005 and 151 in 2009). In order to explain this growth, an analysis was made of the latest NIP, which was in force between 2000 and 2003. It was the first plan containing specific instruments for biotechnology management. This NIP developed the "Program of Technical Research Promotion", which considered the preferred specific thematic areas of funding of particular interest to the country. In addition, the "Ramón y Cajal" program was introduced to provide research grants for talented young researchers. Nevertheless, the momentum in the biotechnology sector may actually be due to the creation of two public foundations: "Spanish Foundation for Science and Technology" (FECYT) and "Genoma España". Both act as agencies for monitoring the quality of science and its management. Genoma España also manages part of the resources allocated to biotechnology scientists in Spain and promotes and oversees the transfer of technology from universities and PROs to business. Several authors [33-35] confirm that the production of scientific research and technological innovation depends on the structure of the NIS and driving sectors, suitably supported by human and financial resources.

When R&D spending in the private sector exceeds the corresponding amount spent in the public sector, labor productivity tends to grow [36]. However, public engagement is vital for offsetting the absence of private venture capital in Spain.

Cases like the German NIS are flexible and consider the situation of the different regions. In this sense, regions like Bavaria have created public agencies that provide seed and early-stage capital. On the other hand, numerous private venture capital firms and investment banks are resident in the Munich area, so there is no need for public intervention in biotechnology development [12].

Therefore, encouraging private investment in research in Spain and stimulating the creation of companies (spin-offs) from the research system give stability to Spanish biotechnology. Data shown after 2005 in Figure 1A confirm this premise. As in the German case, encouraging private investment in R&D in regions accumulating capital seems to make sense, although public bodies should probably be responsible for the development of biotechnology in those areas with less presence in the financial sector.

The private biotechnology sector pursues international patent protection, so it does not feature in the data on national patents. However, given that the public sector is the largest national patent owner, according to the SPTO, and public investment in R&D in Spain exceeds private investment, national patent data allowed us to analyze the management of research in the public biotechnology sector in Spain.

Figure 2 shows the distribution of the biotechnology patent applications filed in Spain since 1991, with 1282 biotechnology patent applications being made by the Spanish public sector, including universities, PROs and other Regional Research Centers (RRCs). The private sector filed 389. After breaking the public sector down into its main components, the following values were obtained: Universities, 717; CSIC, 358; PROs (without CSIC), 81; and RRCs, 126.

Spanish public universities are exempt from patent fees, so in order to compare the results of the scientific performance of the public and private sectors, university patent data were eliminated. Without the contribution of public university patents, the number of public patents was 563. This figure is still higher than the private sector, but now the difference is smaller.

After using "status of patent" to explain the public and private management of patents, mismanagement in the Spanish public sector has been described [37]. It is assumed that patents are withdrawn by their owners when they do not provide benefits. Thus, the percentage of patents in force in an organization can be related to the benefit these organizations gain from their patents. However, high percentages of patents in force may also mean a low level of interest and the forgoing

of their exploitation by their owners and managers. This situation is particularly important in the case of public knowledge management.

Conclusions

This paper contributes to an understanding of the reasons behind the evolution of biotechnology in Spain. Due to Spain's current financial woes, and also to the focus of its NIS, the public sector should be the target of studies of this nature. Although Spain has a widespread tendency to stimulate private investment in R&D, it is still a country in which the bulk of the spending is made by the public sector. R&D expenditure in Spain reached its zenith in 2008. The growth in investment in R&D from 2007 to 2008 was between 1.27% and 1.35% of GDP. At the same time, GDP grew from €1.053.537 million to €1.088.124 million. These data show that 2008 was the peak year in spending on R&D (in absolute terms) and headed Spain in the right direction for technological and industrial development. By contrast, investment in R&D in Spain has fallen from 1.39% of GDP in 2009 (with a slightly lower GDP than in 2008) to 1.33% in 2011.

After confirming biotechnology as one of the sectors most sensitive to economic investment, the government has to intervene in the development of biotechnology. This intervention should not only be financial. The public authorities should foster technology transfer from universities and PROs to industry. In many cases, academic research is poor at perceiving the state of the industry. It should therefore stimulate the creation of spin-offs, as besides being an incentive for researchers, they would create new job opportunities and promote the creation of a powerful biotechnology industry that contributes to the country's economic future. One of the key points in this matter is the rigidity with which the state manages patents. Easy handling of patents by TTOs may well boost the knowledge transfer process.

Compared with international patent data, the national patent data analyzed in this study suggest that the Spanish authorities need to internationalize and industrialize their science in order to recoup their investments in R&D. The results recorded by the private sector confirm that patents with only national protection are insufficient to complete the process from science to business. At the same time, these kinds of patents are confirmed as an accurate indicator of the quality of science in countries with large public investments.

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